

EFFECT OF PROCESS PARAMETERS ON MATERIAL REMOVAL RATE OF WEDM FOR AISI D7 TOOL STEEL

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ABSTRACT

Wire electrical discharge machining (WEDM) is used in industry for machining complex profiles with high accuracy in conductive material. In the present work, the parametric optimization method using Taguchi method is proposed for WEDM of steel grade AISI D7 component. Three process parameters are selected for this investigation; Pulse on-time, Pulse off-time and wire feed. The experimentation is conducted by using Taguchi's L_9 orthogonal array. Signal to Noise ratios of the Material removal rate for all experiments are calculated. The results are analyzed using analysis of variance (ANOVA) and response graphs and presented. The results obtained are used for the selection of an optimal combination of WEDM parameters for proper machining of AISI D7 to achieve better material removal rate.

KEYWORDS: WEDM, Pulse on-Time, Pulse off-Time, Wire Feed, Material Removal rate

INTRODUCTION

Wire electrical discharge machining or WEDM is process not only used for machining ferrous and non-ferrous alloy but also materials of any hardness which are electrically conductive. Due to continued development of mechanical products, the demand for alloy materials (used in forestry tools and equipments, mining tools, structural applications etc.) with high hardness, toughness and impact resistance is increased. Such materials are difficult to machine by conventional machining method.

WEDM provides the best alternative for machining conductive, high strength material for generating intricate shapes and profile. The WEDM machine is specialized in cutting complex contours or fragile geometry that would be difficult to produced using conventional cutting method. The broad capabilities of WEDM allow it to cater to the needs of the aerospace and automotive industries and nearly all areas of conductive material machining.

Y.M. Puri (2004) used fuzzy logic in the Taguchi method to optimize WEDM process with multiple quality characteristics. The work-piece material used was high carbon high chromium die steel. Experimental results confirm that this approach was simple, effective and efficient for simultaneous optimization of material removal rate and surface finish in EDM. This methodology can be used with various work material, electrode to build computer aided process planning system of WEDM with the goal of automation.

H. Singh (2009) investigated on the effect and optimization of machining parameter on material removal rate in WEDM operations. The experimental studies were conducted under varying pulse-on time, pulse-off time, gap voltage, peak current, wire feed and wire tension.

The effect of process parameters were studied on MRR for H-11 using one factor at a time approach.

S.S. Mahapatra (2007) studied the relationships between various control factors like discharge current, pulse duration, pulse frequency, wire tension, wire feed and responses like material removal rate, surface finish and kerf. This finally resulted in a valid mathematical model. Genetic algorithm was employed to optimize the WEDM process with multiple objectives. The study demonstrates that the WEDM process parameter was adjusted to achieve better material removal rate, surface finish and cutting width simultaneously.

PujariSrinivasRao (2010) carried out work on parametric optimization method for WEDM of Aluminium BIS-24345 alloy using Taguchi's robust design. Experiments were conducted under different conditions of pulse-on time, pulse-off time, peak current, flushing pressure of dielectric fluid, wire feed rate, wire tension, spark gap voltage and servo feed setting. Material removal rate was considered as performance characteristics. This method used was for obtaining the optimal combination of parameters. Mathematical and artificial neural network models were developed relating the machining performance and process parameters.

Anish Kumar (2013) focused on experimental investigation on material transfer mechanism in WEDM of pure titanium. The effects of machining parameters such as pulse on time , pulse off time, peak current, spark gap voltage , wire feed and wire tension on the material removal rate, overcut and surface roughness for pure titanium in WEDM process were explored. The selected machining samples were analyzed using energy dispersive X-ray analysis, scanning electron microscope and X- ray diffraction techniques. It was observed from the results that a significant material transfer occurred from dielectric as well as electrode on the work surface either in free form or in compound form.

$$\left(\frac{1}{y_1^2} + \frac{1}{y_2^2} + \frac{1}{y_3^2} + \dots + \frac{1}{y_n^2} \right) \div N$$

TAGUCHI METHOD

In the Taguchi method, experimental values of outputs are transformed into signal to noise (S/N) ratio. Signal represents the desirable value (i.e. the mean for the output characteristics), and noise represents the undesirable value (i.e. the square deviation for the output characteristics). It is denoted by 'η' with a unit of db. In this investigation the characteristics that higher observed values result into better machining performance, it is known as "higher the better". The characteristics that lower observed values result into better machining performance is called "lower the better". Hence, the characteristic of "higher the better" is selected for obtaining optimum metal removal rate.

S/N ratio for material removal rate,

$$\eta = -10 \log_{10} (\text{MSD})$$

$$\text{MSD} = \text{Mean squared deviation from the target value of the quality characteristics} = \quad (1)$$

Where y_n : Results of Observation,

N: Number of repetitions

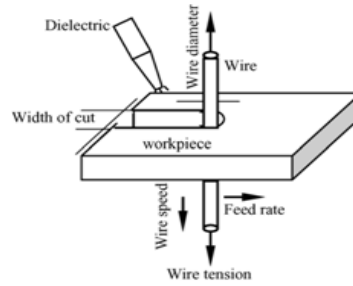


Figure 1: Wire-EDM Process

EXPERIMENTAL DESIGNS

Experimental Set-up and Wire Electrode

Experiments were performed on a CNC wire electrical discharge machine (Model: 'SprintcutElpuls 40 A DLX'). A negatively charged brass wire with diameter of 0.25 mm was used as the tool. The size of the work-pieces considered for experimentation on the WEDM is 50 mm x 10 mm x 6 mm. The chemical composition of the specimen material given in percentage of mass is as follows, C=2.15-2.50, Cr=11.5-13.5, Mo=0.7-1.2, V=3.8-4.4, Cu=0.25, Mn=0.6, Si=0.6, S=0.03, P=0.03 and base metal Fe. For each experiment the combinations of the 3 input parameters viz. Pulse-on time in the range of 110-118(μ s), pulse-off time in the range of 31-51(μ s), wire feed rate in the range of 4-6(mm/min), all having 3 levels (Table 1) is used. These were selected from literature and initial experimentations.

Table 1: WEDM Parameters and Levels

Sr. No	Parameters	Symbol	Level 1	Level 2	Level 3
1	Pulse on time (μ s)	T_{On}	110	115	118
2	Pulse off time (μ s)	T_{Off}	31	41	51
3	Wire feed (mm/min)	W_f	4	5	6

DATA COLLECTION

Material removal rate is calculated with help of two methods. Those methods are given below:

- $MRR = (W1 - W2) / t$, gm/min

Where,

$W1$ = Weight before machining (grams).

$W2$ = Weight after machining (grams).

T = Processing Time in minutes.

- $MRR = K \times T \times V_C \times \rho$, gm/min

Where,

K = Kerf (mm).

T = Thickness of specimen (mm).

V_C = Cutting speed (mm/min).

ρ = Density (gm/mm^3).

In the first method, weight of work pieces before and after is measured on weighing machining having 0.1 mg least count. Time taken for the process is measured with the help of a stop watch.

In the second method, K is kerf (width of the gap) which can be measured by difference between blank and scrap piece sizes. The cutting speed (V_C) is directly displayed on the computer monitor of the machine tool, for various settings of experimental machining operation.

Table 2: Experiments and Results

EX. No	MRR 1	MRR 2
1	0.0141	0.01443
2	0.0159	0.0225
3	0.0219	0.0167
4	0.0254	0.0222
5	0.0234	0.0253
6	0.0315	0.0244
7	0.0396	0.0406
8	0.0219	0.0334
9	0.0295	0.0302

Here we have calculated the material removal rate using both the methods. So we can observe difference in material removal rate from first and second method. The graph shows variation in results by those methods in Figure 2. The range of variation is from 2% to 5%. The variation is not significant and the results are thus validated.

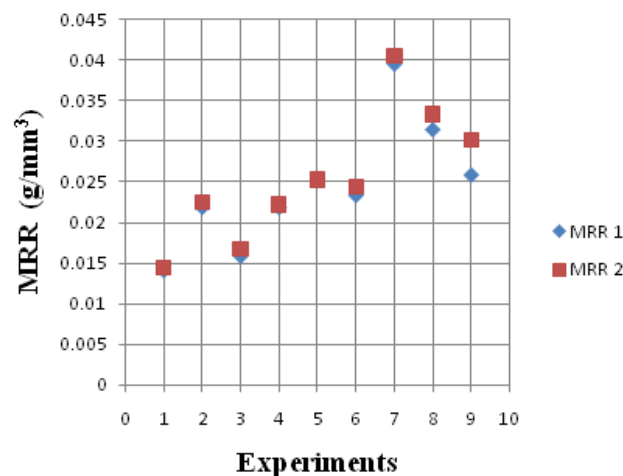


Figure 2: Results by MRR Using Two Methods

DETERMINATION OF OPTIMAL CUTTING PARAMETERS

For the experimental design, an orthogonal array is used. It consists of a set of experiments where the settings of several products or process parameters to be studied are changed from one experiment to another. Results obtained from the experimentation are studied with the help of S/N ratio and ANOVA analysis. By using these results, optimal cutting parameters for maximum material removal rate are obtained. The analysis is made using the software MINITAB 15.

ANALYSIS OF THE S/N RATIO

Higher the better performance characteristic is selected to obtain maximum material removal rate. Parametric combinations of factors are as shown in Table 3

Table 3: L₉ Orthogonal Array

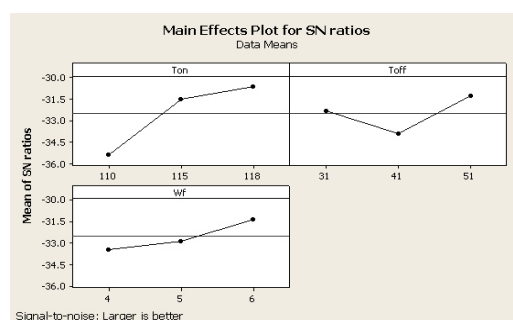
Ex. No	T _{On}	T _{Off}	W _f
1	110	31	4
2	110	41	5
3	110	51	6
4	115	31	5
5	115	41	6
6	115	51	4
7	118	31	6
8	118	41	4
9	118	51	5

Here results from first method are used. There is one repetition for each experiment, hence with help of these, average of material removal rate can found out. The experimental results for material removal rate and the corresponding S/N ratio using equation (1) are shown in Table 4.

Table 4: Calculations for S/N Ratio

Ex. No	MRR 1	S/N ratio
1	0.0141	-37.015
2	0.0159	-35.972
3	0.0219	-33.191
4	0.0254	-31.903
5	0.0234	-32.615
6	0.0315	-30.033
7	0.0396	-28.04
8	0.0219	-33.191
9	0.0295	-30.603

Figure 3 shows the S/N ratio graph for material removal rate. The graph shows that material removal rate increases with the increase in pulse-on time. If pulse-off time increases, then material removal rate decrease. Wire feed rate have less significant effect on material removal rate as compared to pulse-on time and pulse-off time but as wire feed increases, the material removal rate increases.

**Figure 3: Main Effect Plots for S/N Ratio**

ANALYSIS OF VARIANCE

The values obtained from the experiments were analyzed using analysis of variance technique. Analysis of variance is performed to control the process variation and it is used to determine significant parameters which affect the performance characteristics. This decision can be made based on the results obtained. With the help of ANOVA, the parameters can be categorized into significant and insignificant parameters. Here 95% confidence level is considered.

Table 5: Analysis of Variance for S/N Ratio for MRR

source	DF	Seq SS	Adj SS	Adj MS	F
Ton	2	38.511	38.511	19.256	5.87
Toff	2	10.675	10.675	5.338	1.63
Wf	2	7.149	7.149	3.574	1.09
Error	2	6.560	6.560	3.280	
Total	8	62.895			

Where,

DF : Degree of Freedom

SeqSS : Sequence Sum of Square

Adj SS : Adjusted Sum of Square

Adj MS : Adjusted Mean Square

F : Fisher Value

With the help of response table for S/N ratio for MRR, most significant parameter and rank of parameters can easily identified.

Table 6: Response Table for S/N Ratio for MRR

level	T on	T off	Wf
1	-35.39	-32.34	-33.41
2	-31.52	-33.93	-32.83
3	-30.63	-31.28	-31.30
Delta	4.76	2.65	2.11
Rank	1	2	3

RESULTS AND ANALYSIS

From the above results, we were concluding that material removal rate was highly influenced by pulse-on time and pulse-off time. The higher discharge energy, the more powerful explosion and the deeper crater created on the machined area. Pulse on-time (T_{on}) with a contribution of 68.34%, has the greatest effect on the MRR. Parameter pulse-off time (T_{off}) is the next most significant influence 18.98% on the material removal rate. And the parameter, wire feed rate has a contribution of 12.69% to MRR. It is observed that wire feed rate has less effect on the material removal rate as compared to pulse on-time and pulse-off time. Hence if requirement of material removal rate is high, then pulse on-time and pulse-off time must be set high. Optimum material removal rate can be obtained by choosing those parameters suitably.

CONCLUSIONS

The effect of pulse-on time, pulse-off time and wire feed are investigated in machining of steel grade AISI D7 by keeping other process parameters constant. Use of the Taguchi method for the optimization of the wire-cut electric discharge machining process is demonstrated in this work. Based on the experimental results, the conclusions can be drawn as follows.

- Pulse-on time (T_{on}) is the most significant influencing machining parameters, for the material removal rate.
- The parameter pulse-off time (T_{off}), wire feed (W_f) have less effect on the material removal rate.
- For maximum MRR, the recommended optimal parametric combination is A3-B3-C3.

The approach used in this study can be used for other material like steel and aluminum. The effect of thickness of material on output can be studied by using work piece material of different thickness.

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